A Panchromatic
Gamma Ray Burst
MIDEX Mission

Mission Operations Concept Document

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Swift Ground Segment

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REVISION STATUS

This document is controlled by the Swift Ground Segment Project. Changes require prior approval of the PSU Operations Lead and the Ground Segment Manager. Proposed changes shall be submitted to Doug Spiegel, Swift Ground Segment Manager, Omitron, Inc. (301) 474-1700, doug.spiegel@omitron.com.

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1.0 INTRODUCTION

1.1 PURPOSE

The purpose of this document is to establish an operations concept for the Swift mission. The Swift mission involves the 36-month operation of the Swift spacecraft and instruments to perform multiwavelength observations of the afterglow characteristics from Gamma-Ray Bursts (GRBs). Swift plans a comprehensive study of ~ 1000 bursts. This document describes the flight and ground operations activities, staffing, interfaces, and overall operations flow that support the requirements for Swift mission planning, scheduling, commanding, monitoring, and science data delivery to the Swift Data Center (SDC). It is intended as an introduction to Swift mission operations to a range of users including science team members, student operators, sustaining engineering personnel, and management. While not a requirements document, the operations concepts described here will help guide the development of the Swift Mission Operations Center (MOC) and interfaces to other elements of the Swift Ground Segment.

1.2 SCOPE

The scope of this document includes all operations-related plans for the implementation of the Swift mission, specifically including the following:

- Overviews of the science, spacecraft, instruments, and ground segment
- Flight operations activities including mission planning, commanding, GRB detection and notification, monitoring, flight dynamics support, Targets of Opportunity (ToO) support, and sustaining engineering
- Burst data posting to the World Wide Web (WWW), and science data acquisition and delivery to the SDC
- Operations organization, assigned responsibilities, and management

1.3 APPLICABLE DOCUMENTS

The following documents were referenced during the development of this document. The reader is encouraged to use present and future versions of these documents for further research. Most of the documents are available on the Swift Project and Ground Network for Swift (GNEST) web sites.

- "Swift Science Requirements Document", GSFC-661-Swift-SRD, 410.4-SPEC-0005D, March 12, 2001.
- "Swift Mission Requirements Document", 410.4-SPEC-0004, Version 1.4, October 10, 2000.
- "Requirements of the Ground System for the Swift Mission", 410.4-SPEC-0007, Revision 1.0, September 12, 2000, 1.0.
- "Swift Interface Requirements Document", 410.4-ICD-0001A, Version 2.0A, December 20, 2000.
- "Operations Agreement Swift Mission Operations Roles and Responsibilities", Original, April 2001.
- "Swift Ground System Test Plan", Preliminary Version 0.01, May 2001.

- "ICD between the Demand Access System (DAS) and the Space Network (SN) Web Services Interface (SWSI)", 453-ICD-DAS/SWSI, Original, April 30, 2001.
- "ICD between the DAS and DAS Customers", 453-ICD-DAS/Customer, Draft, April 25, 2001.
- "Swift: A Panchromatic Gamma Ray Burst MIDEX Mission", proposal in response to AO-98 OSS-03, August 1998.
- "Swift: A Panchromatic Gamma Ray Burst MIDEX Mission", Phase A Study Report, June, 1999.
- "Swift System Requirements Review", May 8, 2000.
- "Swift Mission Preliminary Design Review", August 29-31, 2000.
- "Swift GNEST PDR", September 13, 2000.

2.0 MISSION OVERVIEW

Swift is a Medium-class Explorers (MIDEX) mission that will greatly expand our knowledge of GRBs, their origin and characteristics. Swift has a panchromatic approach utilizing three instruments. These are the Burst Alert Telescope (BAT) and two Narrow Field Instruments (NFI): the X-Ray Telescope (XRT), and Ultra-Violet/Optical Telescope (UVOT). The mission combines the capabilities and strengths of the National Aeronautics and Space Administration (NASA)/Goddard Space Flight Center (GSFC) and its university and industry partners. Swift has a multi-national approach. The United Kingdom (UK) and Italy are making major contributions of flight hardware and data analysis facilities. The Swift science team has representatives from the United States, the UK, Italy, Germany, Japan and France. Dr. Neil Gehrels of NASA/GSFC is the Principal Investigator (PI).

Spectrum Astro is building the spacecraft bus and leading the Observatory Integration and Test (I&T). NASA/GSFC has program management responsibility and is developing the BAT with flight software from the Los Alamos National Laboratory (LANL). The Pennsylvania State University (PSU) has responsibility for the NFIs and Mission Operations. University of Leicester (UL, UK) is contributing the Charge Coupled Device (CCD) camera and telescope integration facilities for the XRT. The Brera Observatory (OAB, Italy) is contributing the flight spare mirror from the JET-X instrument on Spectrum – X for the XRT. The Mullard Space Science Laboratory (MSSL) of University College London (UCL) is contributing the detectors, mirrors, and other components of the UVOT, using a design which is largely a copy of the Optical Monitor on the X-Ray Multi-Mirror (XMM) satellite. The Italian Space Agency (ASI) is contributing the Malindi ground station in Kenya for spacecraft telemetry downlink and command uplink.

The Swift spacecraft will be launched on a Boeing Delta II 2320 vehicle from the Eastern Test Range (ETR), Florida. A launch date of September 2003 is currently scheduled. Swift will then settle into an orbit at an altitude of 600 km and an inclination of 19 degrees. It will orbit the Earth once every 96 minutes. Following a 30-day checkout period, the nominal 35-month science mission will commence.

2.1 SWIFT SCIENCE OVERVIEW

The Swift mission is the first-of-its-kind for multiwavelength transient astronomy. Swift's primary goals are to determine the origin of GRBs and to use bursts to probe the early universe. The discovery of X-ray and optical afterglow from GRBs enabled by BeppoSAX has revolutionized our understanding of these enigmatic events. We know they are cosmological, located more than halfway to the edge of the visible universe ($z>1$), and involve the most powerful and relativistic explosions known. The origins of the explosions are not understood, but theories suggest that GRBs are the signatures of black hole creation and tracers of star formation at early epochs. It is thought that the initial fireball creates a super-relativistic blast wave resulting in an afterglow, that cascades down from gamma-rays to radio (Reference Figure 2-1).

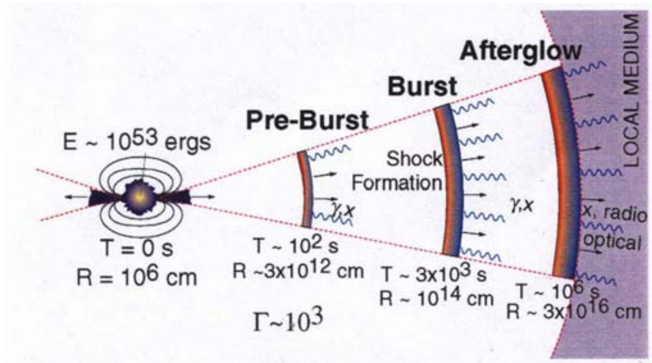


Figure 2-1: Gamma-ray burst fireball model

The Swift multiwavelength spacecraft combines wide and narrow field-of-view (FOV) instruments with rapid response to GRBs to enable a study of GRB afterglow characteristics. The comprehensive study of ~ 1000 bursts will provide information on GRB origins, blast wave evolution and interaction with its surroundings, and identify different classes of bursts and their associated physical processes. The BAT, a 2-steradian wide-field gamma-ray camera, will detect and image ~ 320 GRBs per year (range 170-480 GRBs per year, depending on extrapolation below the threshold of the Compton Gamma Ray Observatory (CGRO)/Burst and Transient Source Experiment (BATSE)), with 1-4 arcmin positional accuracy. The Swift spacecraft then automatically slews within 20-70 seconds to point the narrow field X-ray and Ultra-Violet (UV)/optical telescopes at the position of each GRB to determine arcsec positions and perform detailed afterglow observations.

The Swift baseline capabilities are:

- ~ 1000 GRBs studied over a 3 year period
- 0.3 – 2.5 arcsec positions for each GRB
- Multiwavelength observations (gamma-ray, X-ray, UV and optical)
- 20-70 seconds reaction time
- Five times more sensitive than BATSE
- Spectroscopy from 0.2 to 150 keV
- Grism spectroscopy covering 200 to 600 nm
- Six color imaging covering 170 to 650 nm
- Capability to directly measure redshift
- All observations publicly distributed; position and initial characteristics within seconds

Using Swift positions, it will be possible to both identify the host galaxy and locate the afterglow within it. A redshift measurement will be made from the afterglow itself to give distances and luminosities. The early notification of GRBs by Swift will enable observation by the most advanced ground- and space-based telescopes to gather high quality spectra during the early, brightest phase of the afterglow. In addition to the GRB observations, the Swift BAT will perform a hard X-ray sky survey that is 30 times more sensitive than the most complete previous survey (HEAO A-4). Swift's survey, which will not affect GRB observations, gives the potential of discovering a new population of absorbed Seyfert 2 galaxies that are predicted to exist, based on measurements of diffuse hard X-ray emission, and to be one of the most abundant types of Active Galactic Nucleus (AGN).

2.1.1 Science Goals and Objectives

The Swift Science goals and objectives for the nominal 3-year mission are:

- No. of GRBs observed ~ 1000
- Average response time 50 seconds
- GRB positions 0.3-2.5 arcseconds
- No. of GRBs/year ~320
- No. of arcsecond positions/year 295
- No. of redshifts measured/year ~260

2.2 SWIFT OBSERVATORY OVERVIEW

2.2.1 Spacecraft Overview

The Swift spacecraft, based on flight-proven designs and flight heritage hardware, provides the required structural, thermal, electrical, attitude control, and data/communications support for the three instruments at low risk and cost. Descriptions presented here are for information only. Current information is available elsewhere in design documentation.

The Swift observatory comprises two major mechanical assemblies as shown in Figure 2-2: (1) the Swift Instrument Module (IM), and (2) the spacecraft bus which includes the avionics, single-axis-gimbaled solar arrays, and launch vehicle interface. This modular configuration maximizes parallel development and manufacturing of each assembly, while enabling straightforward, well-defined bus and instrument integration. Figure 2-2 also shows the on-orbit configuration and the location of major subsystems.

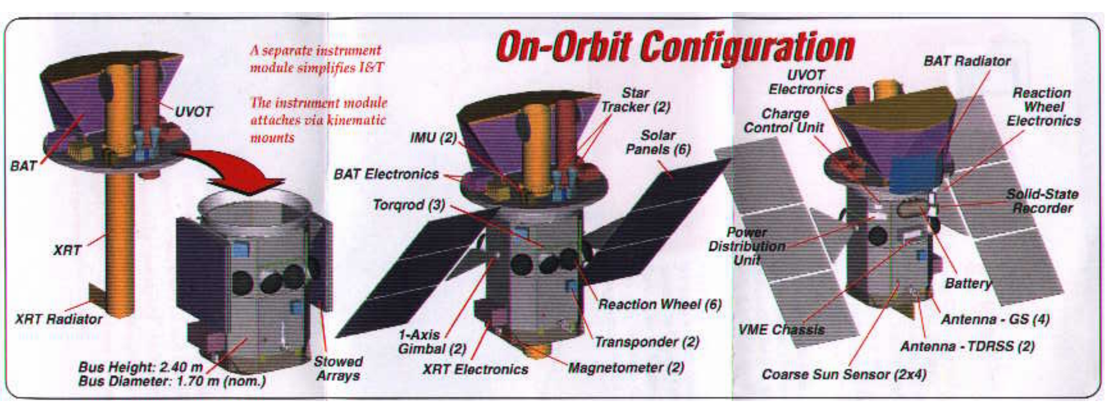


Figure 2-2: Spacecraft and Instrument Module with On-Orbit Configuration

Single-axis gimbaled solar arrays generate electrical power that is regulated and distributed to the instruments and spacecraft subsystems through the spacecraft's electrical power subsystem. The power subsystem includes a battery for power during eclipse periods.

Attitude control, including stable pointing and rapid slewing, is accomplished with six reaction wheels in a zero-momentum bias (ZMB) configuration. Wheel momentum is unloaded by three orthogonal magnetic torquers, using a 3-axis magnetometer for field sensing. Attitude determination is performed on-board using star trackers for fine pointing and a high quality ring laser gyroscope to sense rates. Coarse sun sensors are used for initialization and safe mode operations. A Predict Ahead Planner Algorithm (PAPA) is used to ensure that Sun, Moon, Earth, and Ram constraints are met prior to execution of a slew maneuver (Reference Table 2-1). The top-level requirements for the Attitude Determination and Control Subsystem (ADCS) is shown in Table 2-2.

Table 2-1 Operational Exclusion Zones

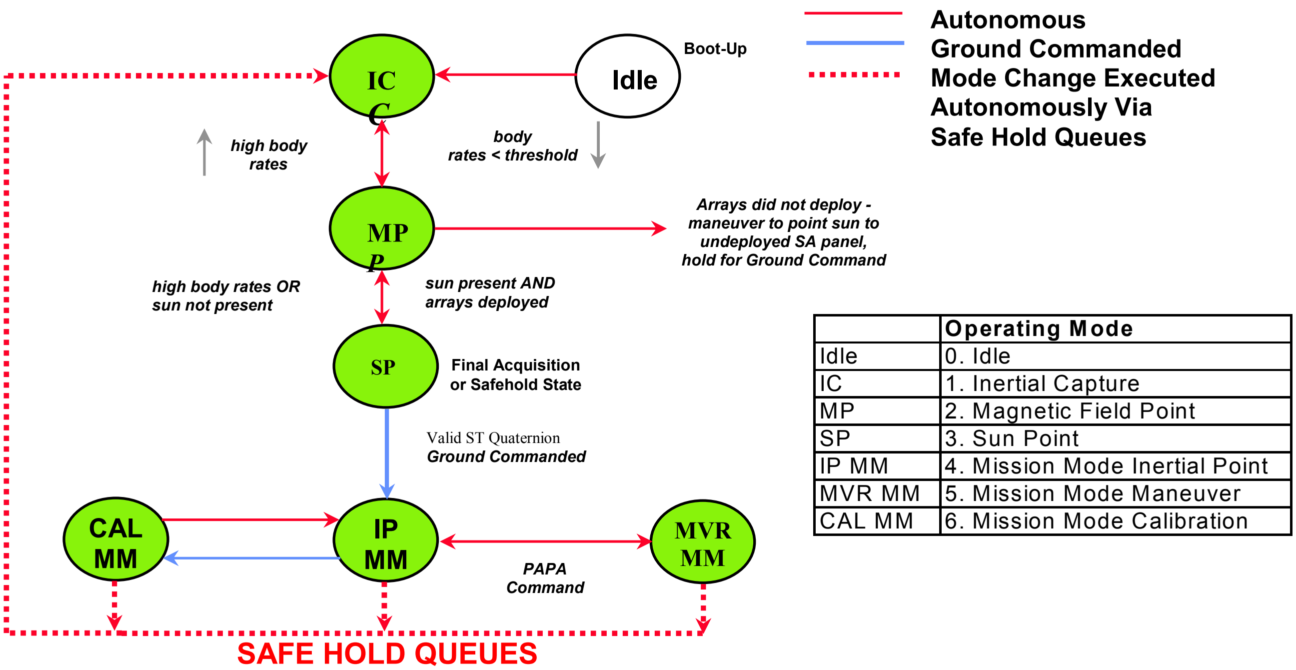
Instrument	Sun	Earth Limb	Moon	Ram
BAT	-	-	-	-
XRT	45°	20°	20°	5°
UVOT	45°	30°	30°	5°

Table 2-2 ADCS Capabilities

Item	Capability
Pointing Control (once settled)	3 arcmin (3σ) each axis pitch and yaw 4.5 arcmin (3σ) in roll
Slew Settling Time	50° in 75 seconds
Jitter (once settled)	1 arcsec (pitch and yaw) over 10 sec. period
Knowledge	5 arcsec, (3σ) each axis pitch and yaw 1 arcmin (3σ) in roll
Knowledge During Slew	1 arcmin (3σ) each axis roll, pitch and yaw

The ADCS has six modes of operation as shown in the mode transition diagram in Figure 2-3. The spacecraft may transition between modes autonomously, by ground command, or on entering safe mode as shown. Exit from safehold to inertial point requires ground command.

Upon initialization, the reaction wheels null out residual rates and the solar arrays are deployed. When rates decrease below a threshold, magnetic field point mode is autonomously initiated. If the sun is present and the solar arrays are deployed, sun point mode is then autonomously entered.



	Operating Mode
Idle	0. Idle
IC	1. Inertial Capture
MP	2. Magnetic Field Point
SP	3. Sun Point
IP MM	4. Mission Mode Inertial Point
MVR MM	5. Mission Mode Maneuver
CAL MM	6. Mission Mode Calibration

Figure 2-3: Mode Transition Diagram

In sun point mode, the star tracker begins to provide the same attitude information as it does in inertial point mode. As the attitude becomes established, the spacecraft begins to maneuver to a safe pointing orientation for the instrument cluster, which is aligned along the spacecraft roll axis. After verification of proper operation, inertial point mode is initiated via ground command.

Normal operations involve pointing to pre-selected regions of the celestial sphere, while the BAT searches the sky in a 2-steradian patch for GRB events. Upon notification of such an event, the on-board ADCS autonomously engages Maneuver Mode, initiating a rapid slew to the indicated target at maximum rates of 2.4° to 3.3°/sec, depending on the target location relative to the combined wheel torque distribution.

Transition to safehold mode is simply a reprise of the inertial capture mode and subsequent automated mode transitions, so a separate ADCS mode is not needed. Safehold can be initiated autonomously (e.g. low power condition) or via ground command. Prior to safehold entry, the instruments are given a 10 second alert to allow for termination of data collection, power-down of high voltage supplies, and safing of optics.

The Swift Thermal Control Subsystem (TCS) design is a cold-biased system employing passive thermal control augmented by the selective use of thermostatically controlled heaters. Thermal control is provided chiefly through the use of multi-layer insulation, and radiative coatings and films. Heaters are used to minimize the impact of eclipse periods on component temperatures. Heat flow is minimized between the spacecraft bus and instrument optical bench using low thermal conductivity flexures.

The Swift Command and Data Handling (C&DH) is based on a standard Versa Module Eurocard (VME) bus. The system is modular and features adequate fault tolerance and internal redundancy to exceed all requirements with ample margin. The Solid State Recorder (SSR) is internally redundant. Multiple addressable segments are available to simplify storage of data by type and to downlink playback by priority. A RAD6000 processor (CPU) performs all spacecraft processing, including command, telemetry, and attitude control, as well as managing the interface for all three instruments. An Intelligent 1553 Interface board acts as the 1553 bus controller and is the primary electrical interface to the instruments.

The telecommunications subsystem is compliant with Swift requirements for communications with the Malindi ground station and Spacecraft Tracking and Data Network (STDN) compatible stations for exchange of commands and data. The subsystem is also compliant with the Tracking and Data Relay Satellite System (TDRSS) for rapid burst alert notifications, spacecraft alert messages, and rapid turnaround commanding. The design is centered on a pair of fourth generation TDRSS transponders.

2.2.2 Observing Strategy and Overview of the Instruments

The Swift strategy is to slew to each new GRB position as soon as possible and to follow GRB afterglows as long as they are visible. To see the earliest phase of the afterglow, new BAT detections trigger an autonomous slew followed by a pre-programmed sequence of observations with the NFIs (See Table 2-3).

The BAT uses a two-dimensional coded mask and a position sensitive solid state detector array to provide both a large FOV (2 steradians) for detecting a good fraction of the bright GRBs and a large collecting area to detect weak bursts. Each source or burst effectively provides an image of the mask on the detector array, and the location of this image can be used to determine the position of the source to 0.3 - 2.5 arcsec. Since GRBs are brief transients, complex fields with many bright sources can be nearly eliminated by background subtraction.

When the BAT detects a count rate increase, it localizes the GRB to <4 arcmin in <10s. The Swift trigger is optimized to detect as many GRBs as possible, and can be adjusted on-orbit by ground command. The detection of a GRB is input to the Figure of Merit (FoM) processor (located in the BAT) to determine if the characteristics of the new GRB give it a higher merit than the current target. If so, the FoM sends a request to the spacecraft to slew to point the NFIs at the GRB position. The spacecraft performs final constraint and safety checks to determine if the slew can be performed. Simultaneously with these activities, messages with the trigger, position, and FOM decision to observe the GRB are telemetered to the ground over the TDRSS Demand Access System (DAS) link. The spacecraft checks that:

- No constraints violated in performing slew, i.e. PAPA determined constraints are met.
- No spacecraft maintenance or calibration functions are affected, i.e. if spacecraft is in a poor power condition, slew may be rejected. This is accomplished by assigning a high priority to these spacecraft conditions within the FoM software.

The Swift Science Team provides the necessary guidelines to set and modify (on-orbit) the FoM processing (BAT detection threshold and parameters for merit calculation) to optimize observing efficiency.

GRBs detected by other spacecraft and/or ground observatories can be observed by uplinking their position as a ToO. The FoM processor, located in the BAT, evaluates the uplinked target and requests the spacecraft to slew, using the same procedure as a BAT-detected GRB.

The XRT uses a high resolution Wolter Type I mirror with a 2-dimensional CCD detector to obtain accurate positions of the GRB and to study its fading X-ray afterglow. The XRT's imaging mode uses multiphoton superposition to give photometry and source location during initial burst observations.

The XRT will provide centroids of afterglows to better than 1 arcsec in detector coordinates within a few seconds. XRT positioning accuracy will be primarily determined by alignment errors and telescope thermal stability. The XRT will also make moderate resolution spectroscopic observations of afterglows after the initial acquisition (~80s) for up to 10 hours after the burst, spectrophotometry for up to 4 days after the burst, and broad-band lightcurves for tens of days.

The UVOT uses a Ritchey-Chrétien telescope with two Micro-Channel Plate (MCP) detectors. These are photon counting devices which provide capability for detecting very low signal levels over a broad wavelength range. An 11 position filter wheel provides spectrophotometry, and two grisms can be used to obtain low resolution spectra of the brightest bursts.

Once Swift has slewed to a new burst, the UVOT acquires a 100s exposure of the target field. The area around the XRT GRB position is compressed and telemetered to the ground within 50 seconds over the TDRSS DAS link. The "postage stamp" image is automatically distributed by the GRB Coordinates Network (GCN), only a short time after the BAT trigger, XRT position, and other burst messages. During the next ground contact, the full frame of the finding chart image is telemetered as well as the sequence of 1000s images in the different filters. These finding charts will contain at least 15 serendipitous stars listed in existing astrometric catalogs, allowing sub-arcsec positioning. This capability to provide rapid optical images of the GRB field over the WWW will enable quick identification of optical or infra-red (IR) counterparts and subsequent observations by ground- and other space-based facilities. The UVOT has a protection mechanism, whereby the high voltage on the MCPs is reduced when bright (M_B<10) stars or Earthlight (25° of the limb) are in the instrument FOV. The UVOT also contains a catalog of bright star locations and planet ephemerides to supplement the hardware protection by also lowering the high voltage when known bright stars and planets (including the four brightest minor planets) are within the FOV.

Table 2-3: Typical Swift GRB Observation Timeline

Time (s)	S/C Event	Time (s)	MOC Event
0	GRB	8	BAT location distributed
10	Slew begins	12	BAT light curve distributed
60	GRB acquired		
65	XRT image	71	XRT location distributed
90	XRT spectrum	105	XRT spectrum distributed
160	UVOT image	243	Optical finding chart distributed
7200	UVOT filters complete		
$\sim 10^4$	Ground station pass	$\sim 10^4$	All burst data sent.
Note: Times in this table are expected time, based on anticipated system performance. The completion of the UVOT filters is the elapsed time-on-target.			

2.3 SWIFT DATA PHILOSOPHY

Each of the three Swift instruments rapidly produces alert messages for downlink via TDRSS DAS and prompt delivery to the science community via GCN. Swift data is rapidly collected and processed into standard formats and distributed to the Swift Science Team and made available to the general science community. All Swift data will be made available from the SDC and the international data centers. Proposals are not needed to participate in Swift Science.

2.3.1 Science/User Community

The Swift Science Team is made up of world experts in GRB astronomy, theory, space instrumentation, multiwavelength follow-up observations, and outreach. The team is primarily from the U.S., U.K. and Italy. Swift supports the general science community by rapidly making the data publicly available and in responding to ToOs.

2.4 GROUND SYSTEM ARCHITECTURE OVERVIEW

The Swift Ground System provides for:

- Radio Frequency (RF) communications with the spacecraft
- Spacecraft & instrument monitoring and control
- GRB alert notification
- Mission Planning
- Science data processing
- Science data archive and distribution

These functions are performed by existing and new facilities. A Swift Ground System mission architecture overview is shown in Figure 2-4.

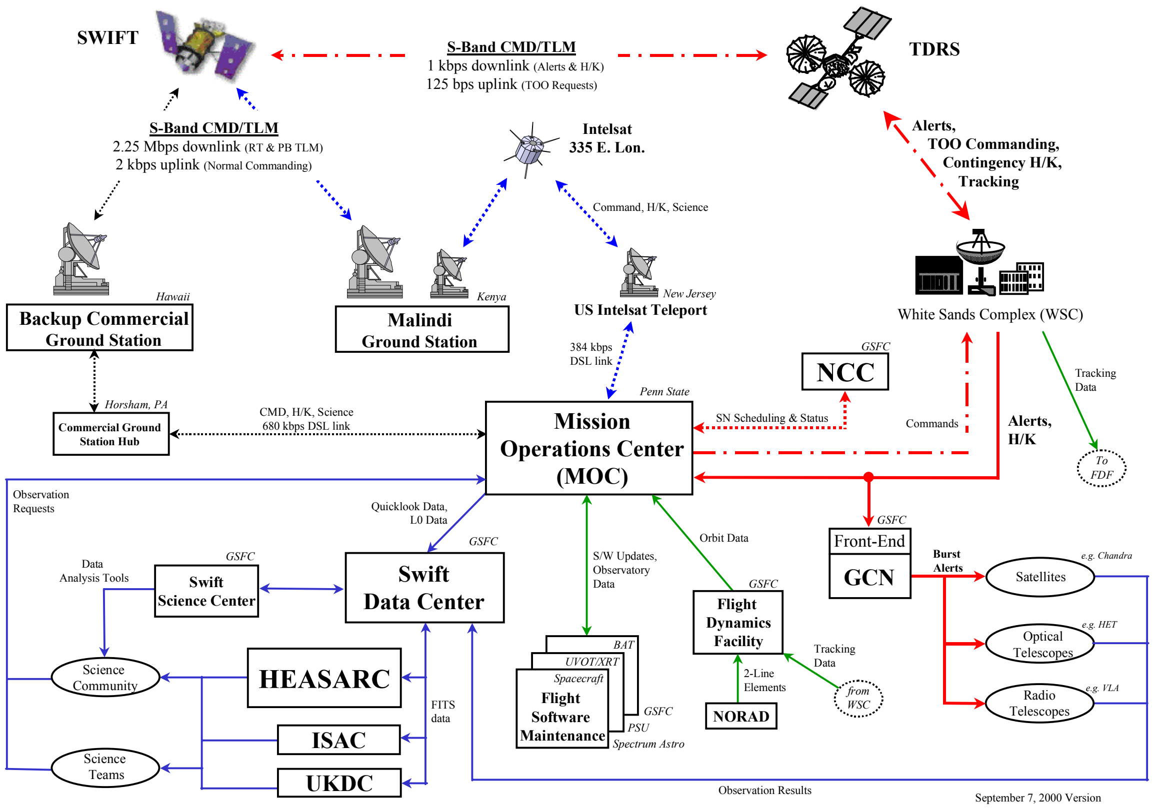


Figure 2-4: Swift Mission Architecture

2.4.1 Malindi Ground Station

The Malindi ground station in Kenya provides space-to-ground RF communications with the Swift spacecraft. The station supports simultaneous S-band science and engineering data acquisition at 2.25 Mbps and S-band command (CMD) functions at 2 kbps. The ground station uplinks spacecraft CMDs received from the MOC, and provides real-time (RT) or playback (PB) S-band telemetry (TLM) and pass statistics to the MOC during each pass. The CMD and TLM data are transferred over an Intelsat link between the MOC and the Malindi station. ASI provides Malindi station operations, including the transmission of TLM to and receipt of CMD from the Intelsat spacecraft. Approximately eight passes per day will be scheduled by the MOC to support mission communication requirements during nominal on-orbit operations.

2.4.2 TDRSS

The TDRSS DAS provides near continuous S-band downlink coverage for low rate telemetry. This service provides the downlink of GRB alerts to the ground for rapid delivery to the science community via GCN. Low rate State of Health (SOH) data can also be provided to support contingency operations and Launch and Early Orbit (L&EO). The spacecraft can determine autonomously when to transmit data via TDRSS. Quick response commanding is available via TDRSS Multiple Access (MA) forward service over S-band at 125 bps for ToO requests, contingency operations and L&EO support. The DAS will communicate information to and from the MOC via the Space Network (SN) Web Services Interface (SWSI). Use of the TDRSS service is scheduled using the SWSI to communicate via the Network Control Center (NCC) at NASA/GSFC.

2.4.3 Commercial Backup RF Ground Station

A commercial ground station provides backup S-band CMD and TLM communications during contingency situations and during L&EO mission phase. It is currently planned to use the Universal Space Network (USN) station in Hawaii. The interface to the MOC is via the commercial ground station hub in Horsham, PA. This capability will provide for S-band downlink at 2.25 Mbps and S-band command functions at 2 kbps.

2.4.4 Ground Communications Network

The Swift ground communications network provides data transport between the MOC at PSU, State College, PA and several ground network interfaces. The MOC will interface with the SDC, the Flight Dynamics Facility (FDF) and the NCC at NASA/GSFC, the White Sands Complex (WSC) in NM, the U.S. Intelsat Teleport in New Jersey, the commercial ground station hub in Horsham, PA, and the spacecraft vendor (Spectrum Astro) in Gilbert, AZ. All communication data links into and out of the MOC are the responsibility of PSU. These include arranging CMD and TLM functions between the MOC and the Intelsat spacecraft, where these functions must be coordinated with those provided by ASI to complete the primary space-to-ground communications link via the Malindi station. The connection with the commercial ground station hub is accomplished with a communication data link for CMD and TLM functions. For TDRSS support, GSFC will manage the link between WSC and GSFC, and the MOC will utilize Internet Protocol Operational Network (IONet) services for the link between GSFC and the MOC. The link from the MOC to the SDC will be used for transferring both quick-look and production level 0 (L0) data sets. ToO requests from the science community to the MOC are handled primarily through a web-based form. Data-line security is predominately provided by a firewall that controls the boundaries between three separate network subnets: open, protected, and closed (Reference Section 3.4.11).

2.4.5 Swift Mission Operations Center (MOC)

The MOC, located at PSU, State College, PA will operate the Swift satellite and instruments. The MOC will support pre-launch operations, launch and 30-day checkout, normal and contingency operations. PSU, under the direction of the PSU Operations Lead, has responsibility for implementing the MOC and overall mission operations. Spectrum Astro provides spacecraft bus training for the Flight Operations Team (FOT) pre-launch, and is responsible for spacecraft launch processing and initial 30-day post-launch checkout. The Science Operations Team (SOT) includes instrument scientists from the XRT and UVOT development teams. The BAT team provides training of the SOT in BAT monitoring, maintenance, and science planning.

The MOC performs all spacecraft and instrument mission planning, commanding, monitoring, and L0 data processing and delivery to the SDC. The MOC provides rapid response for the follow-up of new GRBs detected by the FoM software on-board, and ToOs input from the science team or science community. The MOC incorporates automation of spacecraft operations and data processing to permit a small operations team and "lights-out" operation, and to speed data processing and response to GRBs and ToOs. Archive of all raw and L0 data for the mission is provided off-line with rapid retrieval of the last 7 days. A 30-day on-line archive of housekeeping telemetry, command transmissions, and MOC processing statistics and status is maintained.

An overview of the MOC architecture is shown in Figure 2-5. The MOC is based on the Integrated Test and Operations System (ITOS), and commercial-off-the-shelf (COTS) hardware and software tailored for Swift mission support. ITOS provides all command and telemetry functions, such as front-end processing, command and telemetry processing, real-time monitoring, and archiving. Satellite Tool Kit (STK) supplemented by other COTS and/or government-off-the-shelf (GOTS) provides flight dynamics functions for mission planning and science planning. The Data Trending and Analysis System (DTAS) will allow engineers to review spacecraft status and trend data from remote locations (such as Spectrum Astro, Instrument teams). Computer security with use of firewalls and other techniques prevents intrusion and disruption of operations.

2.4.6 Swift Data Center (SDC)

The SDC converts Swift L0 data into Flexible Imaging Transport & System (FITS) files and standard data products using an automated processing pipeline. The format of the FITS files is consistent with Office of Guest Investigator Programs (OGIP) standards. The data sets are organized by target to facilitate later scientific analysis. Quick-look data products are made on a shorter time scale using less complete telemetry and a similar processing pipeline. The SDC will create and maintain a database of results for public access through the WWW.

The SDC delivers processed production data to the High Energy Astrophysics Science Archive Research Center (HEASARC) at NASA/GSFC and to data centers in the UK and Italy, which will in turn serve them to the public. The data centers provide expertise in the scientific analysis of Swift data. The HEASARC will store all in-flight data, relevant calibration data, analysis software, and documentation.

2.4.7 Swift Science Center (SSC)

The Swift Science Center (SSC) assists the science community in the scientific analysis of Swift data. The SSC has the lead role in developing the software tools needed to convert Swift telemetry into FITS files and to perform scientific analysis of the Swift data. After launch, the SSC updates the analysis tools as the understanding of the techniques utilized improves with experience. In addition, the SSC maintains documentation of the Swift data and results, provides user guides, provides online data analysis recipes, and other information for use by the science community. The SSC will also help to spread the word in the lay community through outreach activities.

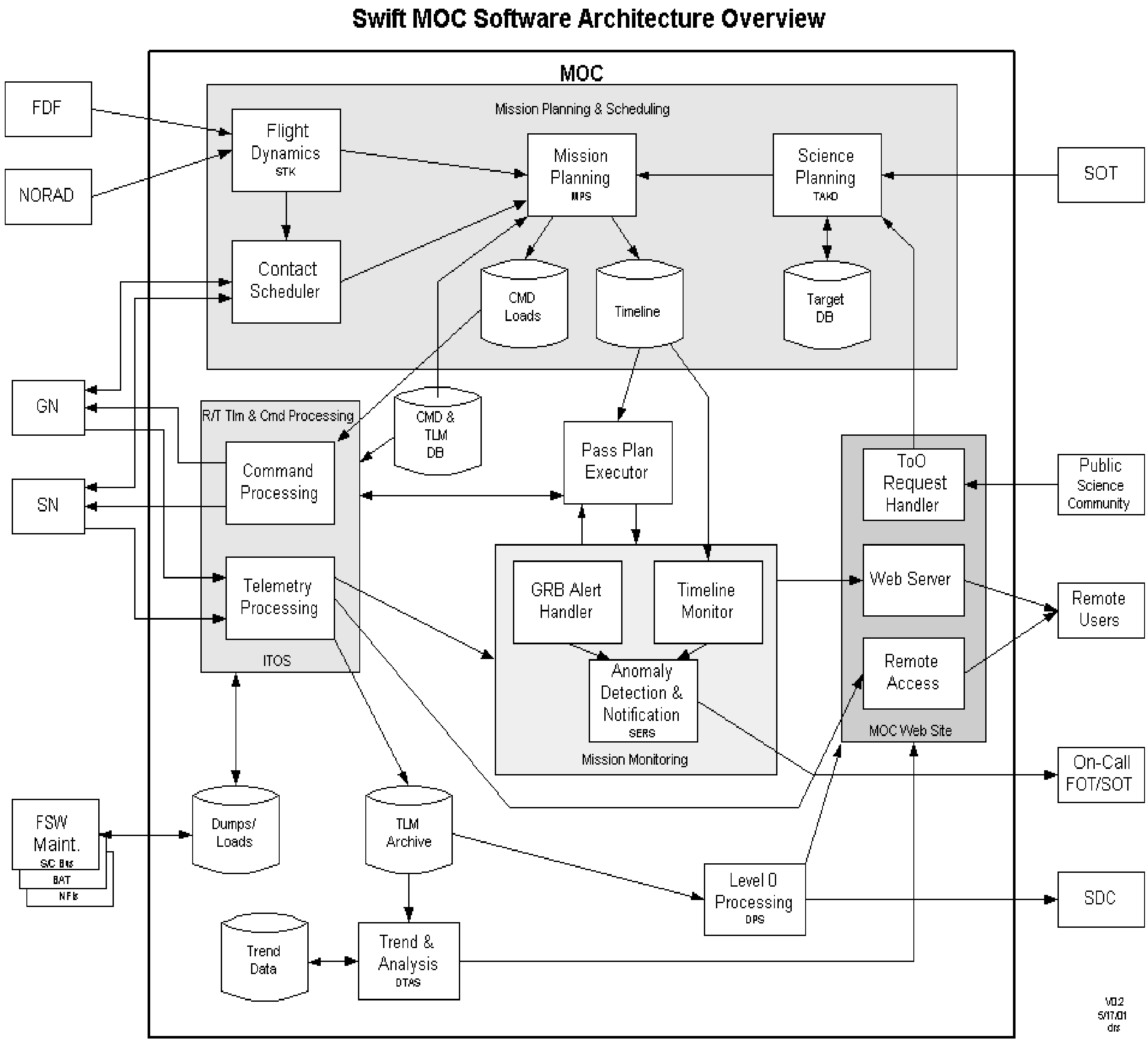


Figure 2-5: Swift MOC Architecture

2.4.8 GRB Coordinates Network (GCN)

The GCN distributes location and light curve information for GRBs detected by all spacecraft capable of detecting GRBs to interested members of the science community. The rapid dissemination of Swift alerts and finder fields will enable ground observatories and operators of other spacecraft to plan correlative observations. The GCN is an existing system with sufficient capacity to support Swift. The SOT will subscribe to the GCN to receive notification of GRBs detected by other spacecraft.

2.4.9 HEASARC/Data Archival

The HEASARC is the permanent archive for Swift data products, calibration data and documentation. All data products will be placed in the HEASARC and mirror archives in Italy and the UK. These archives will make the data available electronically to everyone, regardless of affiliation. The data will be automatically processed by the pipeline as soon as it is downlinked, and will flow directly to the archives without a proprietary period, with the minimal technologically feasible delay. Data will be archived throughout the life of the mission.

2.4.10 International Data Centers

The UK Data Center (UKDC) at the University of Leicester and Italian Swift Archive Center (ISAC) at OAB, Milan archive the FITS files and standard products. They provide ready access to the data and expertise in the analysis for local users. The SDC and SSC support these data centers as needed.

2.4.11 Education and Public Outreach (E/PO)

Swift has a substantial Education and Public Outreach (E/PO) Program, which reflects NASA Headquarters' commitment in this area. Seven projects are included under this program to reach millions of people of all ages to capitalize on the public excitement over GRBs. These include a major web-site development, television productions, curricular materials, collaboration with teacher organizations to disseminate workshop materials, and participation in the Appalachian Region Project for under-privileged children.

2.4.12 Spacecraft Vendor

Spectrum Astro, in Gilbert, AZ, will have a dedicated Swift Remote Engineering Station. From this station, systems and subsystems engineers will maintain familiarity with Spacecraft SOH long-term trends and ongoing operational activities, and maintain proficiency with the trending and analysis retrieval and tools. The necessary data can be retrieved via the WWW or other provided client software. This allows minimum response time to anomalies.

3.0 MISSION OPERATIONS

Swift mission operations encompass all activities from operations concept development through the termination of on-orbit operations and science data collection. Mission operations during the normal operations phase are the responsibility of the PSU Operations Lead with implementation by the Swift Ground Segment. The Swift Ground Segment has responsibility for development of the Swift MOC, implementation of the RF communications for normal and backup operations, elements of the ground network for supporting MOC functions, and training and implementation of the FOT for Swift operations. Spectrum Astro is responsible for spacecraft launch processing and initial 30-day post-launch checkout.

The Swift MOC is to be developed and configured at PSU, State College, PA in readiness for pre-launch operations, launch and 30-day checkout and normal operations. During the normal operations phase, the MOC will be staffed by ground segment engineers (the FOT) and instrument scientists (the SOT). The FOT is supplemented by PSU student operators managed by the Swift Ground Segment; the SOT is supplemented by PSU graduate students in astronomy. A 5-day single-shift staffing plan will be used. The mission operations concept discussed in this document is designed to support these operations.

3.1 MISSION PREPARATION

The Swift mission is considerably cost constrained requiring each segment of the mission to be attentive to efficiency and cost effectiveness. The Ground Segment has been involved from the proposal stage to ensure that efficient mission operations capability is designed into all systems from the beginning. The ground system is designed for speed and flexibility both in distributing burst alerts and data and in receiving scientific input for mission planning. The automation of spacecraft operations and data processing is being implemented to allow for a small FOT and “lights-out” operations during non-staffed periods.

Mission operations preparation includes the definition of spacecraft and instrument operations requirements, coordination with external support organizations to define operational interfaces, and the development of operations plans, procedures, and other documentation. Mission Operations preparation also includes simulations and training for the Swift FOT and SOT.

3.1.1 Requirements Analysis and Documentation

The Swift Ground Segment coordinates with the spacecraft and instrument teams to fully define operational requirements of the spacecraft bus and instruments. Coordination with the Swift Science Team defines science operations requirements, goals and constraints. This information is included in documentation prepared to clearly define all operating requirements, limits and capabilities. It further provides a basis for generating spacecraft and instrument operations procedures for use by the FOT.

Swift operations include not only the operation of the spacecraft and instruments, but also the operation of the ground system itself. Operational interfaces with external organizations (e.g.; commercial RF ground stations) are defined and documented during the pre-launch phase along with internal system operating requirements. MOC routine and contingency operations procedures are developed based on all requirements.

3.1.2 Training

FOT training starts with the development of a comprehensive training plan. FOT training includes formal classroom training, spacecraft and instrument systems training, documentation review, hands-on console training, simulations, and a formal evaluation and certification process. The Swift Training Plan includes instrument and spacecraft systems training by the instrument teams and spacecraft contractor, general satellite operations training, and mission-specific procedures training for Swift operations. MOC ground segment training includes hardware and software overviews and hands-on practice. Additional training on spacecraft and instrument operational requirements is obtained through FOT participation in Observatory I&T activities.

SOT training begins during instrument development, including preparations for and participation in Observatory I&T. Training continues with the development of operations plans and procedures. The SOT will also receive some formal training in the use of MOC systems for instrument operations and mission planning.

Pre-launch simulations are used to train, exercise, and evaluate FOT operators in nominal and contingency situations in all mission phases: launch, early orbit, science data collection, spacecraft maneuvers, and maintenance functions. Pre-launch simulations include End-to-End (ETE) operations with the ground stations and spacecraft at the GSFC I&T facility, as well as internal data flows at the MOC. Post-launch, training of new FOT operators and student operators will include on-the-job-training (OJT) mentoring by experienced personnel.

3.2 PRE-LAUNCH OPERATIONS

Pre-launch Operations for Swift is defined as any pre-launch activities that include the use of the Swift MOC as an operational entity prior to the actual launch countdown. Ground system and operations readiness will be determined by a series of ground system tests and operations simulations. The test program and schedule will be documented in the “Swift Ground System Test Plan”. Procedures for spacecraft and ground system testing will be developed to allow maximum reuse for on-orbit L&EO and normal operations phases.

3.2.1 Element Acceptance Testing

A structured, incremental approach is used for ground system testing, verification and readiness. This includes a modular build strategy for ground system development, where each build or module is integrated and tested. Build or module testability is determined during design and code walkthroughs. Module testing confirms satisfaction of design requirements. A system acceptance test plan ensures quality assurance by placing emphasis on the integrity of the delivered modules and the associated user documentation, and adherence to standards. Acceptance testing ensures the readiness of the operational system.

3.2.2 Observatory Integration and Testing

At approximately L-12 months, a MOC system is configured at GSFC to support Observatory I&T conducted by Spectrum Astro. The FOT will participate alongside the spacecraft and instrument teams to support problem resolution with the MOC command and telemetry system, and for testing and confirmation of the MOC command and telemetry database. The main goal in supporting this testing is to allow the FOT access to actual telemetry and become familiar with both the spacecraft and instruments which reduces risk for later ground system testing and operations.

3.2.3 RF Compatibility Testing

RF Compatibility tests will verify the compatibility between the spacecraft and the ground communications systems (TDRSS, Malindi and commercial ground stations). All RF testing will be conducted when the spacecraft is in the Observatory I&T facility at GSFC. The ground stations will provide portable RF test equipment to interface with the spacecraft and the MOC. The TDRSS RF Compatibility testing will utilize the Simulations Operations Center (SOC) at GSFC, the Compatibility Test Van (CTV) to communicate with a TDRS, the DAS at WSC, and forward data to the MOC at GSFC.

3.2.4 Spacecraft Interface Testing

Spacecraft Interface Testing will verify compatibility between the observatory (spacecraft and instruments) and the MOC system. Testing will include real-time telemetry and commands, loads, data and memory dumps, and Burst Alert/TDRS messages. Spacecraft Interface Testing will initially receive telemetry in a “listen-only” mode from the spacecraft during spacecraft I&T (at Spectrum Astro facility) and observatory I&T (at GSFC). The Spectrum Astro Hot Bench simulator will be utilized to ensure that all obvious interface problems are found and resolved prior to the use of the spacecraft.

3.2.5 Mission Readiness Testing

Mission Readiness Tests will verify that all ground systems, interfaces, and operations elements meet the mission requirements. These integrated system verification tests are conducted prior to the ETE tests and mission simulations. During this test phase, certain tests may be repeated as needed to maintain readiness.

3.2.6 End-to-End (ETE) Testing

ETE tests involving all ground system elements verify a proper data flow configuration between the spacecraft and the MOC. The elements include the spacecraft (at the GSFC I&T facility), ground station RF equipment (at the GSFC I&T facility), the SN, the MOC equipment loaded at PSU, and the SDC at GSFC. Commands are sent from the MOC through the RF equipment to the spacecraft. Similarly, telemetry is sent from the spacecraft through the RF equipment to the MOC. Burst alert processing is verified through the SN. Finally, the MOC transfers L0 science data to the SDC. All practical operational data flows and processing steps are exercised and verified.

Further ground system ETE tests are performed between the MOC and ground stations to verify proper configurations between the ground stations and the MOC. To test a ground station to MOC interface ETE, recorded data is played back from the ground station to the MOC. MOC commands are sent to the ground station, and recorded for subsequent verification.

3.2.7 Mission Simulations

Mission Simulations will be designed to emulate the operations environment of different mission phases, including L&EO, nominal science collection, and spacecraft maintenance activities. The focus of mission simulations will be the continued training of the FOT, SOT, Spectrum Astro, and ground system support teams, procedure validation, database verification, and system testing in the actual operations environment. There are plans for three Mission Simulations tests for L&EO, normal, and contingency operations. L&EO simulations are basically rehearsals of the L&EO timeline that exercise the launch scripts. Normal operations simulations generally rehearse a typical day-in-the-life once the spacecraft has been declared operational. Contingency simulations are rehearsals of various anomaly situations that may occur on-orbit. NASA will provide lead support in planning, documenting, and conducting all operations simulations needed prior to launch. This support will be provided primarily by the Mission Operations Readiness Lead. NASA will ensure that the collection of simulation activities prior to launch demonstrates the overall readiness of the operations staff, products, and processes.

3.3 LAUNCH AND EARLY ORBIT CHECKOUT

The early orbit checkout phase begins at launch and is scheduled to complete in the first 30 days of the mission. Spectrum Astro conducts launch and 30-day checkout from the PSU MOC. The L&EO Director will be provided by Spectrum Astro and will generally be the lead in all aspects of mission operations during the L&EO phase. The FOT supports these activities by executing the command and control interface to the spacecraft, scheduling ground station and TDRSS support, and performing other activities which are part of nominal operations. The SOT and personnel from the BAT team support instrument activation and verification steps in the L&EO timeline. Coordination of activities and resolution of conflicts will be the responsibility of the L&EO Director.

Launch operations begin with the start of the defined launch countdown. Prior to launch, pre-launch activities are controlled from Kennedy Space Center (KSC) with launch readiness status provided to the FOT on a regular basis. Final checkouts are performed pre- and post- mate to the Boeing Delta II 2320 launch vehicle. After Delta 2320 nose-cone closeout (L-TBD hours), insight into the spacecraft status is limited to a small number of hardwired safety-critical parameters and commanding is precluded. Pre-defined launch phase procedures describe actions to be taken by Spectrum Astro Launch Processing team in the case of nominal and non-nominal spacecraft status. As part of the launch countdown, the MOC Director will report the readiness to support launch of the MOC and its communication links. Similarly, the GNEST Lead will report the readiness of the remainder of the ground system. .

There is no telemetry or command capability from liftoff until the first contact with the spacecraft via TDRSS. The Spectrum Astro and MOC personnel have no insight into the spacecraft or instruments status until the first on-orbit contact. At that time, the MOC will receive real-time data as well as housekeeping data recorded since spacecraft initialization following separation. Launch control center personnel will keep the MOC informed of launch status and will provide the orbit insertion vector.

During the initial ground contact, Spectrum Astro engineers and MOC personnel will checkout the following:

- Initial SOH verification
- Verify attitude orientation, current/voltage as expected
- Initial command verification
- Verify Solar Array and Antenna Boom deployments
- Download stored SOH telemetry

Operations during the early orbit mission phase will be controlled by pre-defined, certified procedures and focus on verifying spacecraft and instruments' health and proper configuration. Operations during this phase are lead by Spectrum Astro and supported by the FOT, SOT, and instrument teams. The MOC will be manned continuously until completion of the 30-day checkout. The FOT provides support as necessary during this period.

All spacecraft and instrument systems are verified for nominal functionality during the 30-day checkout. A timeline of checkout activities will be created from inputs from Spectrum Astro and the instrument teams. Spacecraft and instrument operating modes are validated, operational procedures are updated based on flight system characterization, and the trending of system data is initiated. The culmination of the checkout will be a declaration by Spectrum Astro that the spacecraft functionality and interfaces have all been validated and NASA accepts the delivery on-orbit. The declaration will be followed by a Project-level review to assess post-launch and operational performance of the spacecraft, instruments and ground segment. At the conclusion of a successful checkout, responsibility for spacecraft operations is handed over from the Spectrum Astro operations team to PSU. The FOT will then have responsibility for operating the spacecraft and instruments and overall mission planning, while the SOT will have responsibility for the performance of the instruments and science planning.

3.4 NORMAL OPERATIONS

Normal operations begin at the conclusion of the 30-day checkout, and encompass all activities necessary to collect and process science data and maintain the spacecraft, instruments, and ground systems on a routine basis. The normal operations phase is planned to terminate 3 years after launch, unless the mission life is extended.

The majority of Swift's observing timeline is spent on observations of GRB afterglow. The pre-planned mission timeline is revised daily during the five day work week in response to new bursts and ToOs. The pre-planned observations will be stored and managed by the spacecraft stored command processor (SCP) and will provide a means of performing multiple observations without ground commands. The most critical spacecraft activity occurs after a burst trigger.

When a GRB is detected by the BAT, an alert and a subsequent location telemetry message is sent to the ground via TDRSS to the GCN and the MOC, then automatically to the GRB community. Once the BAT determines the location of the GRB, the FoM will coordinate between observing the newly detected GRB and the pre-planned targets, using a merit value comparison. Pre-planned targets have ground assigned merit values and newly detected GRBs will be assigned merit values onboard. If the FoM determines that the new target is more meritorious, it will send the spacecraft a request to slew. The spacecraft makes final checks on constraints and critical actions. The slew decision, BAT burst location and light curve, XRT position and spectrum, and UVOT postage stamp finding chart are relayed through TDRSS as they become available.

The spacecraft actions following a burst are autonomous through the initial set of observations to obtain multi-wavelength light curves and energy distributions. The on-board decision process may be revised after launch as appropriate to optimize burst characterization and follow-up observations. When observations are finished or the new burst can no longer be observed (e.g., due to Earth occultation or other constraints), the satellite returns to its pre-burst mission timeline at the current time. During staffed hours, the on-duty MOC science planner and mission-planning engineer determine if the mission timeline should be revised based on the burst's initial characteristics and consideration of observations preempted by the new burst. At all other times, the on-call science planner will be paged to examine the burst's characteristics to determine if an immediate replan of the mission timeline is warranted. If the science planner determines that the burst is of high priority, then the on-call FOT engineer will be paged and requested to uplink a revised science timeline.

The TDRSS DAS provides near continuous downlink coverage for downloading GRB alerts and finding charts for delivery to the GCN and for alerting the ground of spacecraft emergencies. Alarm messages, in standard-format state-of-health telemetry, are autonomously sent to alert the ground of critical alarm events such as safehold or low voltage. On ground initiated command, real-time housekeeping data can also be transmitted for spacecraft and instrument monitoring and contingency support.

Swift will respond to other scientific opportunities, which includes GRBs detected with other satellites, X-ray transients, and unusual behavior from known sources. Anyone in the astronomical community is able to submit a ToO request for observations by sending a brief, scientific justification to the MOC via a web form. MOC operators are paged for those requests that require immediate action. Each ToO request is evaluated by the PI or his designated representative from the Swift Science Team to decide whether to interrupt the pre-planned schedule. Acceptance of ToO requests requiring rapid response is expected no more than once a week.

Approximately eight passes per day will be scheduled by the MOC to support mission communication requirements during nominal on-orbit operations. The FOT manages data storage on the SSR and its downlink via a ground station. Full science data downloaded through ground passes provide more detailed information about the afterglow. Automated processing of the telemetry stream begins with the production of L0 data at the MOC, and continues through a production data pipeline developed and maintained by the SDC, with associated data centers in the UK and Italy. Quick-look processing will be delivered to the SDC within 90 minutes of the MOC's receipt of the telemetry, and standard data products produced from quick-look posted to Swift's web site daily. Complete sets of standard data products will be deposited in the HEASARC within two weeks. Science analysis tools are provided and maintained by the SSC.

3.4.1 Mission Planning and Scheduling

The FOT and SOT perform mission planning and scheduling during the regular 5-day operations shift. Scheduling several days in advance is expected to accommodate planning for weekends and holidays. These pre-planned schedules are revised approximately daily to accommodate new GRBs in the science target list. Key planning information begins with a science target schedule and regular spacecraft activities, and includes target occultation, accommodation of operational exclusion zones (reference table 2-1), passage through the South Atlantic Anomaly (SAA), and available Malindi ground station passes.

Guidelines for mission science planning are provided by the Swift Science Team. Guidelines include criteria for prioritizing GRBs and ToOs and strategies for follow-up observations. Criteria include the scientific importance of the GRB or ToO and assessment of efficiency for viewing based on operational constraints. The importance will depend on the GRB's characteristics, including observed source fluxes, light curves, spectra, and characteristics of the likely optical host. These guidelines will be updated based on contingency analysis of Swift and follow-up data.

The SOT selects targets and prepares a preliminary schedule based on science requirements and observing constraints in an attempt to optimize viewing times. The SOT will utilize burst alert and quick-look data products for the generation of the science timeline. The BAT team will provide additional targets to ensure sufficient coverage of the all-sky survey. The SOT generates and provides the science timeline to the FOT. The FOT will generate the mission timeline based on the science timeline, ground station and TDRSS contact schedules, and any engineering activities. This planning results in generation of time-tagged command loads for uplink to the spacecraft.

Malindi ground station contact scheduling is based on predetermined criteria (minimum length of pass, number of passes per day, maximum time between passes, etc.) and an updated orbit vector. The Malindi ground station provides the pass schedules to the MOC. The scheduling procedures for use of Malindi will be documented in the MOC to Malindi ICD. Scheduling of the backup commercial ground station will be done via a web-based schedule request form. The use of the commercial ground station for backup support will be documented in the MOC to Commercial Ground Station ICD. Emergency supports will be coordinated with the appropriate ground station via voice links.

The SWSI is the FOT interface into TDRS scheduling and real-time monitoring. The SWSI will be used to schedule near continuous 24 hour TDRS DAS support, monitor schedule changes, provide alert information, and provide service status data. TDRS hand-over schedules are obtained from SWSI for use in mission planning and subsequent uplink to the spacecraft for antenna selection. The SWSI will also allow the FOT to schedule TDRSS MA forward supports using the WSC Transmission Control Protocol (TCP)/Internet Protocol (IP) Data Interface Service Capability (WDISC). The FOT shall provide orbit vectors to the SN using SWSI.

When GRB alerts or ToOs are received outside of the regular 5-day operations shift, the MOC system will utilize pre-defined criteria to determine if the on-call SOT engineer (reference section 4.2.3) is paged. Based on the information received and established guidelines, a decision is made whether to respond with a quick schedule revision or wait until the next regular shift.

3.4.1.1 Flight Dynamics Support

Swift mission planning and scheduling activities require time-tagged orbital event lists based on propagated Swift orbits. During the first week of the mission, FDF support will be provided to perform orbit determination from tracking data. The tracking data will be obtained through current TDRSS tracking services. The FDF will provide orbit products to the MOC. This interface will be further defined in the Swift Project Service Level Agreement (PSLA).

Once FDF support is completed, Swift orbit determination will use North American Air Defense Command- (NORAD) provided two-line elements. NORAD under its own resources tracks everything in low Earth orbit, including the Swift satellite. NASA/GSFC continually receives the latest NORAD “satellite catalog” of up-to-date satellite state vectors in the form of two-line elements. NASA/GSFC Orbital Information Group (OIG) publishes these elements on the WWW. Once updated orbit information is obtained, the MOC will provide updated state vectors to the ground stations and SN.

3.4.1.2 As-Flown Timeline

When GRBs are detected, the Swift spacecraft may autonomously slew to directly point the NFIs at the burst based on calculations by the FoM software on-board. These autonomous operations result in changes to the planned timeline generated by the MOC planning and scheduling function. The MOC produces an as-flown timeline for each day of the Swift mission to enable analysis of the downlinked science and engineering data for planning additional Swift afterglow observations. The as-flown timeline contains a time-ordered list of target names, target positions, instrument configurations, maneuver times, and orbital events affecting available observing time.

3.4.2 Commanding

The Swift spacecraft may be commanded via a 2 kbps S-band uplink provided by the Malindi and/or commercial backup ground stations. Swift may also be commanded via a 125bps uplink provided by TDRSS MA forward links. The Malindi ground station is primarily used for normal operations support with the commercial ground station providing backup capability as needed. Quick response commanding is scheduled through TDRSS for contingency and L&EO operations, and for ToO commanding.

The MOC utilizes Spacecraft Test and Operations Language (STOL) procedures to control Swift command activities during ground station and TDRSS contacts. These procedures provide a set of command operations, which are prepared and checked out pre-launch and maintained under configuration control. The use of STOL procedures enables automation of routine operations during off-shift periods. The spacecraft and instrument command and telemetry database is maintained at the MOC. The database identifies critical commands, which could pose a potential danger to the spacecraft or any of the three instruments. Protection is provided to prevent unintentional use of these critical commands.

Three types of spacecraft commanding are used for the Swift spacecraft.

- Real-time commands
- Stored Command Processor (SCP) Absolute Time Sequence (ATS) table loads
- SCP Relative Time Sequence (RTS) table loads

Real-time commands are uplinked from the MOC for immediate execution during spacecraft ground station or TDRSS contacts. During L&EO operations, real-time commanding can consist of nearly any spacecraft activity. During normal operations, real-time commands will primarily consist of ATS and RTS table loading, SSR redumping activities, clock correction factor updates, and unplanned instrument activities. Swift uses the Consultative Committee for Space Data Systems (CCSDS) Command Operation Procedure - 1 (COP-1) protocol to verify receipt of real-time commands during a ground station contact. For TDRSS contacts, receipt of real-time commands is confirmed by end-item telemetry verification. The MOC maintains an electronic log of real-time commands that have been sent and verified. An updated log covering one day of commanding is provided to the SDC within seven days of command execution.

For other than real-time commanding, the spacecraft utilizes SCP ATS table loads. These ATS loads contain time-tagged sequences of commands and are used for the majority of commanded functions on-board the spacecraft. These functions can consist of nearly any spacecraft activity, but will primarily consist of ground station contact sequences, instrument observation sequences and configuration, and various health and safety operations. The ATS loads are uplinked on a daily basis via real-time commands when the MOC is staffed and consist of at least three days of time-tagged commands. The MOC verifies all ATS command loads against operational constraints prior to uplink. Successful uplink of an ATS command load is confirmed by a checksum operation on the entire contents of the ATS load.

For commonly used command sequences, the spacecraft utilizes SCP RTS table loads. These RTS loads contain relative time-tagged sequences of commands. The spacecraft flight software, real-time command, or ATS command can execute or start RTS loads. The RTS loads are uplinked on an as needed basis via real-time command when the MOC is staffed.

3.4.3 Spacecraft & Instrument Monitoring

The MOC is responsible for spacecraft and instrument health and safety monitoring, as well as the verification of nominal mission execution and system status. The MOC monitors received SOH telemetry for out-of-limit situations, and proper spacecraft and/or instrument configuration. STOL procedures or scripts with ancillary software tools allow automation of telemetry monitoring to not only support off-shift periods, but to optimize MOC staffing during the regular 5-day shifts. This allows a small FOT cadre to perform mission planning and scheduling as well as spacecraft and instrument monitoring, and other duties such as ToO support. Automated telemetry processing includes packet extraction, engineering unit conversion, limit checking with alarms, display, and rules verification.

The MOC sends quick-look and production L0 data to the SDC for further processing. The SOT analyzes the quick-look data for science planning and verification of proper instrument function. Any out-of-limit conditions or abnormal spacecraft or instrument function are assessed and responded to using pre-approved procedures, wherever possible (reference section 3.8, Anomaly Resolution). The MOC also performs selected trending of housekeeping and engineering parameters to verify nominal system performance and expected degradation.

The MOC responds to many out-of-limit situations automatically. During off-shift periods, paging is used to notify on-call and backup FOT and SOT personnel of situations requiring operator intervention. The on-call and backup operators have remote access to review system data or burst messages and quick-look analysis. If warranted, they are within close proximity allowing travel to the MOC for performing additional analysis or command operations.

3.4.4 GRB Alert Distribution

The Swift spacecraft and instrument complement are designed to autonomously respond to an observed GRB based on criteria pre-stored in the FoM software. Table 2-3 provides a typical Swift GRB observation timeline. The location of the GRB and light curve obtained by the BAT instrument, a more precise location and spectrum obtained by the XRT, and an optical finding chart produced by the UVOT are distributed to the science community. The information is obtained in the approximate time sequence shown in Table 2-3, downlinked via the TDRSS DAS, and distributed over the GCN at the same time it is transmitted to the MOC.

3.4.5 Systematic GRB Afterglow Observation

GRB observations are initiated by the detection of a counting rate increase in the BAT detector. The BAT transitions from "waiting mode" to "BAT GRB mode". In this latter mode, the BAT alerts the FoM processor of a possible GRB. The BAT produces a background-subtracted detector map, and rapidly converts this map to an image to locate the GRB. This GRB location and initial time-history information on the source are input to the FoM, and downlinked to provide the GRB alert. The FoM evaluates the GRB and, if appropriate, sends a slew request to the spacecraft to point the NFIs at the GRB. Meanwhile, the BAT continues to record light curves of the GRB.

The XRT's three primary design requirements are: (1) rapid, accurate positions to support the GRB alert, (2) moderate resolution spectroscopy, and (3) high time resolution light curves. Moderate resolution X-ray spectroscopy provides important information on the GRB afterglow. The statistical precision of these measurements degrades with declining afterglow counting rates. The light curve measurements can be made in one of two timing sub-modes: (1) fast timing mode, and (2) normal timing mode. Normal timing mode is preferred for measurements of confused fields. To cover the large dynamic range and rapid variability expected from GRB afterglow, the XRT supports several readout modes and can autonomously change readout mode depending on the current target flux. There are three readout modes: imaging mode, timing mode, and photon-counting mode. To cope with rapidly changing source flux, the XRT automatically selects the optimum readout mode, and adjusts the readout and instrument modes accordingly.

- Imaging Mode: multiphoton superposition during initial burst observation to give photometry and source location
- Timing Mode: measurement of source-spectra and temporal variability with resolution of <5 msec.
- Photon-counting Mode: single photon counting mode for spectra and photometry with full CCD spectral resolution and maximum source sensitivity

The XRT is expected to spend most of its time in Timing Mode.

The UVOT's primary design characteristics include: (1) providing a finding chart to assist ground observatories in locating the GRB for correlative observations, (2) UV-optical light curves obtained in a series of filters, and (3) for bright sources, moderate resolution grism spectroscopy. The UVOT has five operating modes:

- Fast Mode. UVOT telemeters time-tagged photon events as they arrive in this mode providing high time resolution
- Imaging Mode. Photon events are summed in this mode over an image frame, where spacecraft pointing drift is corrected over the accumulation period by reference to guide stars within the instrument FOV.
- Transient Mode. This mode is used during settling of the pointing on the target. Photon events are stored in memory on arrival. On location of the target position, only those photon events near the target position are extracted and telemetered.
- Safe Mode. The filter wheel is moved to a blocked position and high voltage on the MCPs is reduced. This mode is used for self protection, when bright stars or Earthlight are in the instrument FOV.
- Engineering Mode. Several engineering modes are provided for instrument evaluation.

The initial UVOT observation of a burst consists of a predefined sequence of exposures using various filters and exposure times. The same sequence is used for the initial observation of every burst, but the sequence definition may be updated by the Swift Science Team as required. Follow-up observations of the afterglow are based on ground-planned, uploaded schedules of command sequences produced by the MOC's mission planning and scheduling function.

3.4.6 Targets of Opportunity (ToO)

ToOs are submitted to the MOC using a web-based form. The decision whether to disrupt planned science operations to observe the ToO is made according to guidelines approved by the Swift PI. The MOC acknowledges receipt of each ToO within an hour, and will inform the ToO requester of its decision within 24 hours. An electronic log is also maintained showing all ToOs received and their disposition. The SOT will be notified via e-mail for each ToO and via page if time critical.

Assessment of a ToO includes: the need for rapid response, the scientific merit and goals of the ToO, the credibility of the request, and its impact on spacecraft resources and ongoing operations. The SOT provides a technical evaluation to the Swift PI. Following a decision by the Swift PI or his representative to observe the ToO, the SOT responds to include the ToO in the operational timeline. Depending on how rapid a response is needed, the position and merit can be uploaded to the FoM or a short-term revision of the schedule can be uploaded via TDRSS or ground contact.

3.4.7 Weekly Activities

MOC activities will primarily be set up on a weekly schedule. Due to single shift operations, most FOT activities occur during typical business hours. Generation of command loads will typically occur each day of the workweek. Mission planning (see Section 3.4.1, Mission Planning & Scheduling) produces command loads of a length determined by valid propagation times. Daily revised schedules are anticipated based on the expected frequency of GRB detections.

3.4.8 Science Level 0 (L0) Data and Delivery

The MOC shall receive all CCSDS-compliant telemetry frames from the Malindi ground station, commercial ground station and the TDRSS DAS link. The L0 processing system will perform processing on all mission telemetry, and maintain the mission archive within the MOC. Functions performed include extraction of science packets, Reed-Solomon (RS) decoding, time-ordering of data, removal of duplicate packets, and generation of quick-look and production data products with associated quality and accounting information. The MOC will forward quick-look and production data products electronically to the SDC.

Quick-look products are generated for each ground-station contact. The MOC creates time-ordered, duplicate-removed data sets and will distribute the quick-look products to the SDC within 90 minutes after receipt of data from a ground-station contact.

The MOC manages the receipt, recording, processing to L0, and archiving of raw and L0 Swift telemetry. This includes managing the on-board spacecraft recorder and scheduling of ground contacts. Daily spacecraft data volume is approximately 5.4 Gbits. Production data will be generated on a 24-hour day boundary. The production L0 data, which is the final, time-ordered, duplicate-removed data sets of Swift telemetry, is archived and delivered to the SDC within 7 days for further processing. The MOC also maintains an archive of the raw telemetry and relevant ancillary data to support any required processing of these data sets.

The MOC is required to provide at least 95 percent of received telemetry in the form of production L0 data sets. A log of data received, processed, distributed and quality control information is maintained. The total ETE mission data loss is expected to be less than 10%.

3.4.9 Data Archival

The MOC archives the raw telemetry files and the L0 data for the life of the mission. The last seven days are also available on-line. The MOC archive is designed primarily to support operations, including off-line analysis, trending, and anomaly resolution. The MOC also maintains a 30-day on-line archive of housekeeping telemetry, command transmissions, and MOC processing statistics and status.

The SDC archives the L0 data it receives from the MOC. The SDC's archive is available to other Swift users and the community on request. The SDC sends processed Level 1 data and standard products to the HEASARC for public access. The HEASARC is responsible for the permanent archive of Swift data, data products, calibration data, and documentation. The HEASARC is a permanent archive for the data from many high-energy astrophysics missions. As a consequence its contents and techniques for accessing the archives are well known to the science community. Data for the Swift Project are archived by the HEASARC for the life of the mission. The International Data Centers provide similar Swift archives for their local users.

3.4.10 Anomaly Resolution

Out-of-limit conditions detected in Swift telemetry or other ground segment operations generate alarms for the FOT and SOT, as appropriate. During off-shift hours, on-call personnel are paged and review remote displays to determine if operator intervention is required. If warranted, personnel will travel to the MOC to resolve the condition or further analyze the anomaly. Sustaining engineering personnel will be contacted as appropriate. Remote engineering stations aid in the speedy analysis and resolution of any anomalies. During normal operations (post-L&EO checkout), the chain of responsibility for different levels of anomalies begins with the FOT for routine out-of-limits. If a spacecraft emergency is declared, the Swift PI is notified and assumes responsibility (See Section 4.2.4.).

The Swift observatory has significant auto-safemode capabilities. The spacecraft automatically places itself and its instrument complement in safehold mode should critical telemetry violations occur. In addition, each instrument will safemode itself should certain conditions occur. Safemode cannot be exited except by ground command. Standard procedures for resolution of anomalies and exit from safemode will be developed to address all known major failure modes.
A Swift operational anomaly tracking system is implemented prior to the start of pre-launch simulations, and is used to track the status of all spacecraft, and instrument and ground segment anomalies for the duration of the Swift mission. The Swift Operations Manager and PSU Operations Lead approve closeout of all anomaly reports.

3.4.11 Computer Security

Special attention is made to computer security in the development of the MOC and other ground facilities to prevent intrusion and potential disruption of operations. Computer security shall conform to NASA Procedures and Guidelines for Security of Information Technology NPG 2810.1. A formal plan will cover internal MOC systems, connections with the PSU network architecture and Internet Service Provider (ISP), dedicated commercial lines for ground station communications, and connections to GSFC that includes the IONet. The separate Flight and Science Operations Local Area Networks (LANs) have their own firewalls and access monitoring functions.

Network security for the Flight Operations LAN shall predominately be provided by a firewall that controls the boundaries between three separate network subnets: open, protected, and closed. The "open" subnet will be only moderately protected and will contain public web servers and other non-critical MOC systems. The "protected" subnet will be very restricted and only allow remote access via encrypted Virtual Private Network (VPN) technology. All commanding and other mission critical systems will be located on the closed network. The closed network will be severely restricted and only allow incoming remote access for telemetry from the ground station and SN systems. The firewall filtering will be based on source and destination IP address and port number.

3.5 SDC DATA PROCESSING

The SDC pipeline data processing system produces Level 1, 2, and 3 data sets and standard products from the L0 data provided by the MOC. The SDC is staffed during normal business hours, 40 hours per week. The pipeline runs autonomously 24 hours a day, 7 days a week; it is activated automatically by receipt of L0 data from the MOC. The pipeline is monitored autonomously, and SDC support staff are called if problems are detected.

A Project Data Management plan (PDMP) describing the Swift data and data products will be available from the SDC. The instrument teams provide simulated data to assist in pre-launch verification of the SDC system. Extensive use of the expertise of the Swift Science Team is utilized in developing the SDC pipeline processing system.

3.6 SSC COMMUNITY SUPPORT

The SSC supports the science community by documenting Swift data and data products by providing guides and advice on performing data analysis. This information is available from the SSC web site, and also from a help desk.

The SSC develops analysis tools used to analyze Swift data and maintains them based on experience with the Swift mission. The instrument teams are responsible for calibrating their individual instruments and providing calibration products to the SSC. The SSC tests these products, and integrates them into the analysis tools to ensure the science community has access to the needed tools for performing Swift data analysis.

3.7 SUSTAINING ENGINEERING

Sustaining engineering functions for the ground segment, spacecraft bus, and instruments are designed to maintain an operational ETE system for the acquisition of science data during the 35-month science mission duration. Sustaining engineering activities are managed and coordinated by the MOC with support from the Spectrum Astro and instrument teams. Sustaining engineering for the SDC, SSC, HEASARC, and International Data Centers are handled by their respective organizations.

3.7.1 Spacecraft Sustaining Engineering

Day-to-day spacecraft operations at the MOC includes the monitoring of real-time and playback spacecraft housekeeping telemetry (reference section 3.4.3) and the creation of an archive of housekeeping data. The MOC routinely generates selected plots and reports on the status of various spacecraft systems, and performs a weekly systems analysis per defined procedures.

The current assumption is that Spectrum Astro will be retained for the duration of the Swift mission to provide routine sustaining engineering support to the FOT. A remote engineering workstation will allow engineers to review spacecraft status and trend data from the MOC data archive. Sustaining Engineering support would include, for example, expert systems engineering analysis, solar array degradation over time, battery performance characterization, and thermal degradation. The contractor submits periodic spacecraft system status reports to the MOC based on review of received housekeeping data. The contractor is also on-call to support anomaly resolution activities, as required.

The current assumption is that Spectrum Astro will maintain the flight software for the spacecraft. Any changes to the flight software are validated before uplinking the software for execution. The Project Configuration Control Board (CCB) will ensure that all changes are proper and that earlier versions of the software are available if anomalies are identified in subsequent versions. A flight software testbed may be used to validate planned updates to the spacecraft flight software.

3.7.2 Instrument Sustaining Engineering

Day-to-day instrument operations at the MOC includes the monitoring of real-time and playback instrument housekeeping telemetry (reference section 3.4.3) and the creation of an archive of housekeeping data. The MOC routinely generates selected plots and reports on the status of various instrument systems, and performs a weekly systems analysis per defined procedures. Analysis of quick-look science data in the MOC tracks instrument performance as the mission progresses, and helps detect any subsystem problems.

The instrument teams provide sustaining engineering support for the Swift instrument complement. Remote access to the MOC archive data allows the instrument teams to review instrument housekeeping data, analyze quick-look science data, and perform trending of selected subsystem parameters. The instrument teams also have local presence at the MOC to verify proper instrument performance. Sustaining engineering and calibration activities are clearly defined pre-launch, and executed and supported on a routine basis by the instrument teams. A periodic report on instrument system status is provided to the MOC, and appropriate information provided to the SSC to support data analysis of Swift data by the science community. Instrument teams and software personnel are also on-call for anomaly resolution support.

Instrument flight software will be maintained by the instrument teams, who will perform configuration control and validate changes to the software loads. Once the loads are validated, they are transferred to the MOC for uplink. The MOC will validate correct instrument destination, check for critical commands, and verify correct uplink of the loads to the spacecraft.

3.7.3 Ground Segment Sustaining Engineering

Sustaining engineering activities for the MOC include periodic upgrade and testing of the MOC hardware and software systems and automated pre-pass interface checks prior to each ground station contact. Data quality monitoring aids in the identification and resolution of hardware degradation in the systems, and configuration management of software and hardware at the MOC ensures efficient, sustained operations. Maintenance contracts are in place with MOC COTS vendors to cover bug fixes, consulting support, and software upgrades for the life of the MOC mission. MOC maintenance procedures are included in the Swift Mission Operations Plan.

The MOC will be responsible for maintaining the configuration of the MOC hardware, software, documentation, display pages, Project Database (PDB), as well as any other items requiring control. The Project CCB will approve changes prior to implementation. The MOC will validate and test certain updates prior to implementation.

Sustaining engineering functions for the ground network and RF ground stations are the responsibility of the contracted service providers. A sustaining engineering plan will be obtained from each service provider to ensure acceptable practices are in place.

4.0 OPERATIONS ORGANIZATION & MANAGEMENT

The Swift mission combines the capabilities and strengths of NASA/GSFC, university and industry partners. Swift has a multi-national science team with representatives from the United States, the UK, Italy, Germany, France and Japan. Dr. Neil Gehrels of NASA/GSFC is the PI.

4.1 SWIFT PROJECT ORGANIZATION

Dr. Neil Gehrels (PI) has overall responsibility and authority for the mission (Figure 4-1 shows the Swift organization chart). The decision making process flows from the PI's delegation of the mission technical management to the Project Manager (PM). Day-to-day project management authority is vested in the PM who oversees the efforts of four major mission segments: 1) Spacecraft Contractor, 2) Instruments, 3) I&T, and 4) Ground Systems.

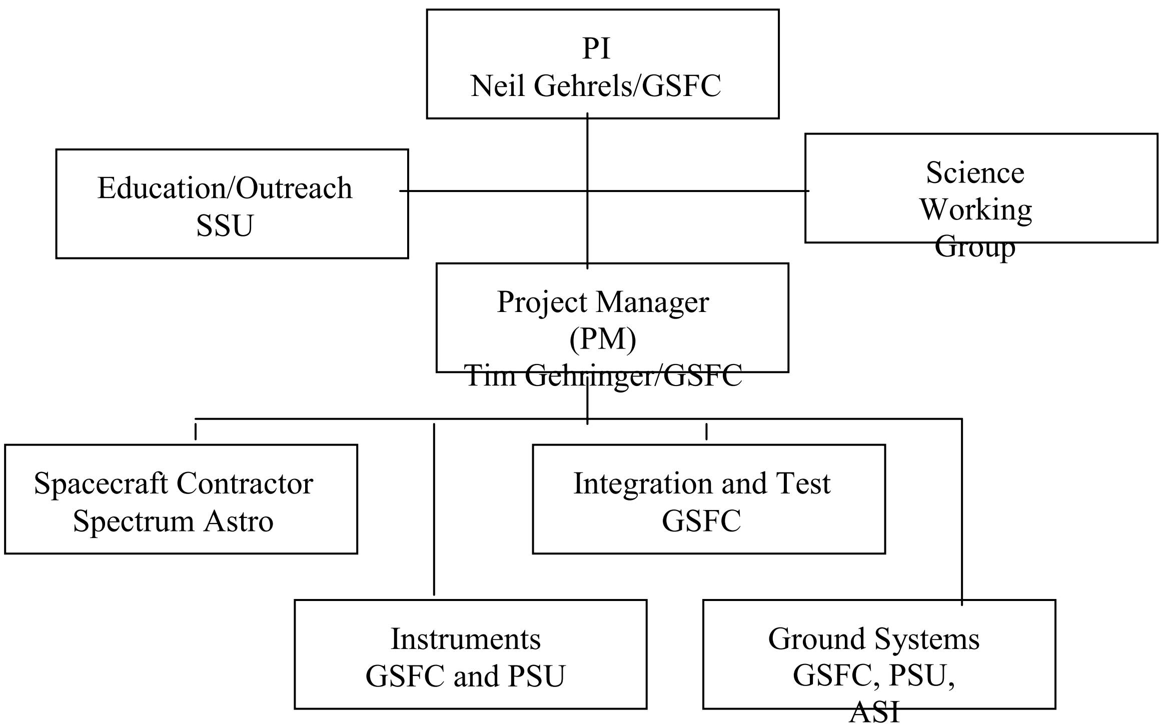


Figure 4-1: Swift Organization Chart

The Ground Systems Manager, Dr. Francis Marshall, is responsible for the delivery of the ground system. Dr. John Nousek of PSU has primary responsibility for the NFIs and oversees the MOC ground segment development and mission operations. These latter activities are under the direction of Dr. Margaret Chester, PSU Operations Lead. The Swift Ground Segment and FOT is provided by Omitron, Inc. of Greenbelt, Maryland under the direction of Doug Spiegel, Ground Segment Manager, who reports to Dr. Chester.

4.2 SWIFT MISSION OPERATIONS TEAM

The Swift mission operations team is a function of mission phase.

4.2.1 Pre-Launch Operations

During the Pre-Launch Operations phase, the mission operations team will include members from NASA/GSFC, Spectrum Astro, the instrument teams, PSU, Omitron, and ASI.

PSU is responsible for providing the physical MOC facility, science operations systems, and SOT personnel to support instrument and science operations. Omitron is responsible for providing the flight operations systems and FOT personnel to support observatory operations and to assist in operating, coordinating, and troubleshooting the ground system. The FOT is responsible for obtaining a thorough knowledge of the spacecraft, instrument, and ground system designs, operations, and associated products.

Spectrum Astro is responsible for delivering the spacecraft on-orbit to NASA (within a L+30 day time-frame), and has the lead role in ensuring launch and mission readiness of spacecraft and associated operations. Spectrum Astro is responsible for providing the FOT (Omitron) and SOT (PSU) with opportunities to become familiar with the spacecraft design and associated operations products, via methods such as training, participation in the product review process and spacecraft testing.

The instrument teams are responsible for ensuring the activation and mission readiness of their instruments, including associated operational products. The instrument teams will be responsible for providing the FOT and SOT with opportunities to become familiar with the instrument design, operations, and associated products, via methods such as training, participation in the product review process and instrument testing.

ASI is responsible for ensuring the mission readiness of the Malindi ground station, including associated operational products. ASI is responsible for providing the FOT and SOT with opportunities to become familiar with ground station, operations, and associated products, via methods such as interface testing and simulations. ASI will provide an RF suitcase that will simulate and verify compatibility with the Malindi ground station.

4.2.2 Launch and 30-Day Checkout Operations

Spectrum Astro conducts Launch and Early Orbit (nominal 30-day) checkout operations from the PSU MOC. Spectrum Astro will provide the L&EO Director who will lead operations activities as identified in the "Operations Agreement Swift Mission Operations Roles and Responsibilities". The L&EO Director will have the authority to give direction to the supporting element personnel as needed to ensure that overall operations support is provided. The FOT provides support in MOC operations and maintenance, and utilizes this phase to enhance FOT training and readiness for normal operations. Figure 4-2 depicts the Swift mission operations organization during L&EO operations.

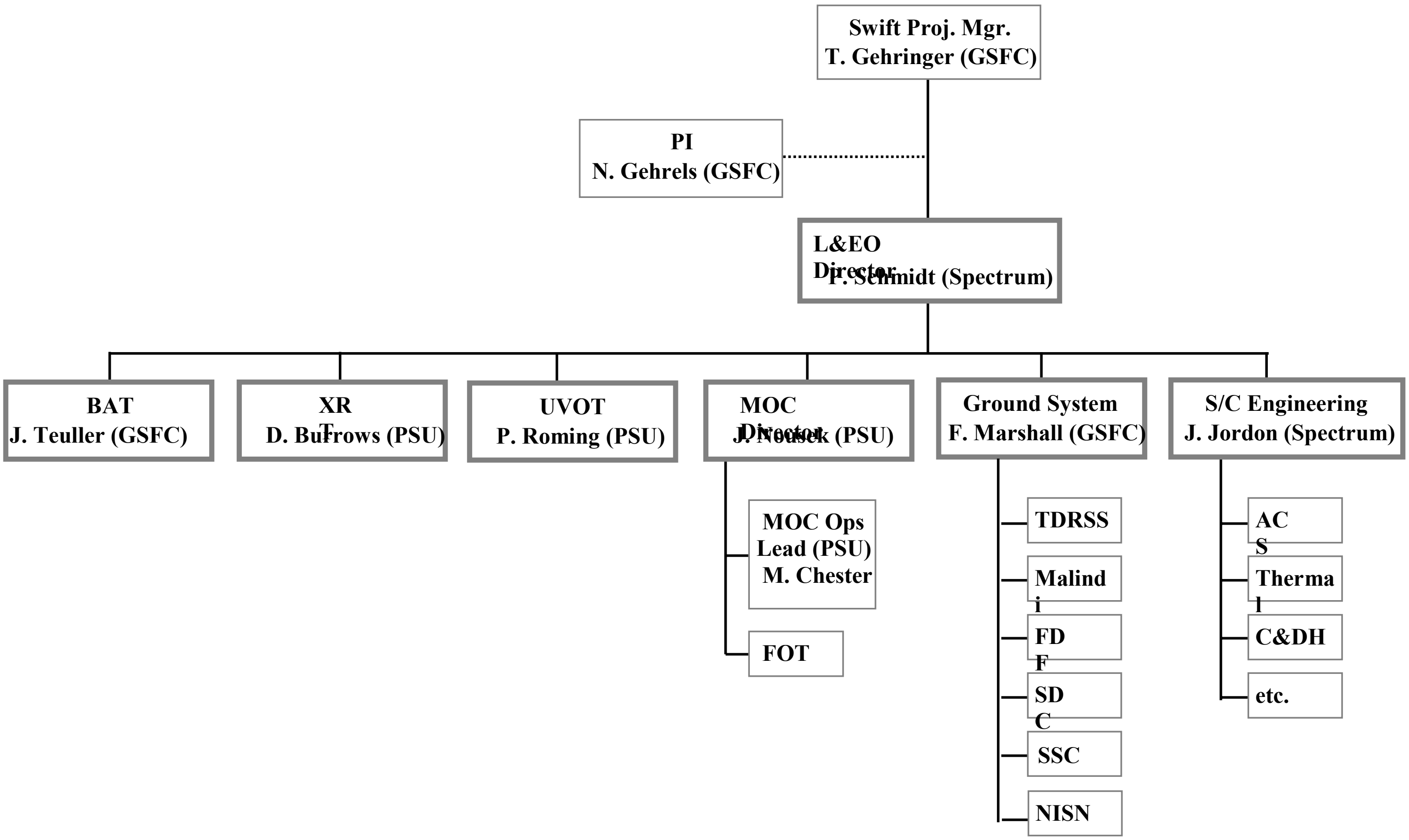


Figure 4-2: L&EO Mission Operations Organization Chart

A launch script incorporating spacecraft, instrument and ground system activities will be developed using inputs from all segments. NASA personnel will take a lead role in putting together the complete launch script. Spectrum Astro is responsible for providing and approving all information related to activation and check-out of the spacecraft interfaces to the instruments. The SOT is responsible for providing and approving all information related to activation and check-out of the instruments.

4.2.3 Normal Operations

At the completion of the checkout of the spacecraft and interfaces with the instruments and ground system, a Project-level review is held. If successful, operational responsibility is handed over to PSU, with support from Omitron. Overall responsibility and authority at the MOC is held by the Mission Director. The FOT (provided primarily by Omitron) is led by the Operations Manager, who has responsibility for spacecraft operations, spacecraft and instrument state-of-health, ground station- and TDRSS-associated activities, and overall mission planning and command upload generation. The SOT is led by the SOT Lead, who has responsibility for instrument operations, support for instrument state-of-health, instrument maintenance and calibration, and science target planning. Figure 4-3 depicts the entire Swift mission operations organization during normal operations.

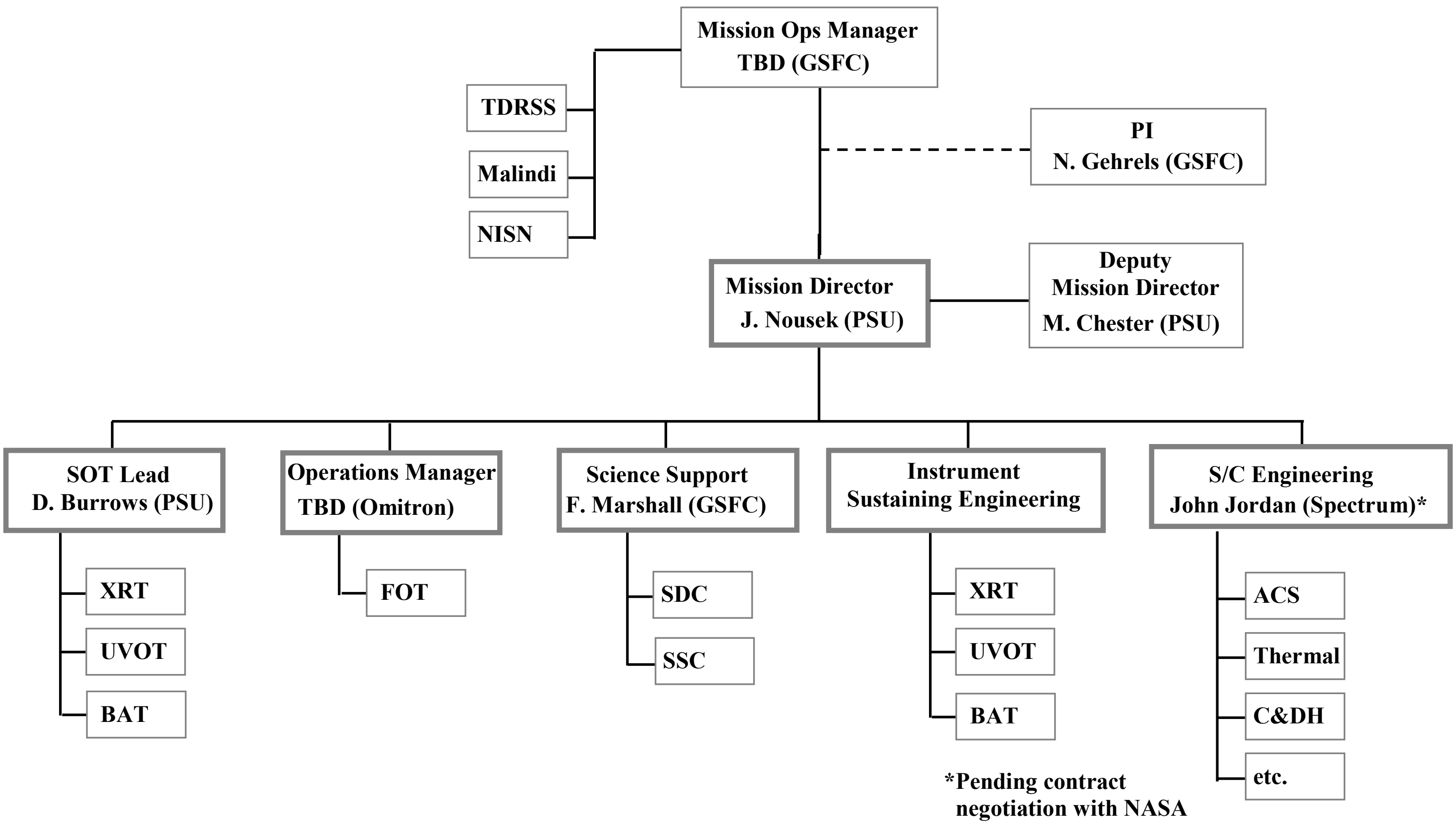


Figure 4-3: Mission Operations Organization Chart

The FOT consists of Omitron operations engineers and PSU student operators. The operations engineers oversee and support routine operations tasks performed by the student operators, and perform critical tasks such as contingency analysis. During MOC staffed shifts one of the operations engineers is designated as Flight Ops Lead. Off-shift duty operators are designated on a rotating basis, and selected from available operations engineers. On-call duty operators respond to pages for off-shift critical anomalies. Flight Ops Leads generate weekly operational status reports for the Operations Manager, who in turn reports to the Mission Director. Operations Manager approval is required for all MOC configuration changes, software changes, and procedure revisions. The Operations Manager is the management interface to external organizations supporting MOC operations (such as the commercial ground station service provider). The Operations Manager is also the technical interface to the instrument teams, sustaining engineers and data processing personnel at the SDC.

The SOT consists of scientists from the XRT and UVOT instrument teams and PSU graduate students. The instrument scientists oversee routine planning and data monitoring tasks performed by students, and perform critical tasks such as contingency analysis. One SOT member is designated as the Science Planner during all MOC staffed shirts. SOT members are chosen for off-shift responsibilities on a rotating basis, and respond to pages for new GRBs, ToO requests, and anomalies.

Support is provided by sustaining engineering teams at Spectrum Astro and off-site instrument teams who perform periodic system status analysis from workstations at their own facilities. Space is provided in the MOC facility for additional personnel as required for special operations. Status summaries are periodically provided to the Operations Manager. The sustaining engineers and instrument teams also provide anomaly resolution support when called upon by the Operations Manager. Management issues are resolved through the Mission Director.

The Swift Science Team provides guidelines to operations for science target definition and priorities. The Science Team also provides updated criteria for the FoM. This input is provided to the FoM developer, and a summary of changes made is given to the FOT and SOT.

4.2.4 Contingency Operations

Routine out-of-limits and non-critical anomalies are dealt with by the FOT and SOT, as appropriate. Persistent or repeating anomalies result in the notification of the Deputy Mission Director and appropriate members of the spacecraft and instrument teams. Anomalies unresponsive to standard procedures will result in notification of the Deputy Mission Director, who will be responsible for their resolution and, if necessary, for declaration of a spacecraft emergency. If an emergency is declared, the responsibility for resolution transfers to the Swift PI, who may call a “tiger team” to develop a solution or alternative operating mode.

4.3 SWIFT SCIENCE TEAM

The Swift Science Team is headed by Dr. Neil Gehrels (NASA/GSFC). The multi-national team has representation from the United States, the UK, Italy, Germany, France and Japan. The Swift Science Team includes scientists from the following organizations:

- NASA/GSFC
- PSU
- University of Leicester (UL)
- Mullard Space Science Laboratory (MSSL)
- Los Alamos National Laboratory (LANL)
- University of California at Berkeley (UCB)
- Instituto di fisica Cosmica (IFC/CNR)
- University of Rome (Italy)
- Astronomical Observatory of Brera (OAB)
- Princeton University
- Satellite per Astronomic X (X-Ray Astronomy Satellite)/Science Operations Center (SAX/SOC)
- Saclay (France)
- MPE (Germany)

- USNO
- NRAO/VLA
- ISAS (Japan)
- Sonoma State University
- University of California at Santa Barbara (UCSB)

The Science Team provides operations inputs on science target definition and priorities, and supports upgrade of the criteria for the FOM.

4.4 WORKING GROUPS

The Swift International Science Working Group (ISWG) headed by Dr. Nicholas White represents the interests of the Swift Science Team.

The GNEST was initiated during Phase B and holds regular staff meetings headed by Dr. Francis Marshall, Ground Systems Manager. GNEST aids in the definition of operations interfaces and requirements. The GNEST includes representatives from the NASA/GSFC Swift Project, SDC, SSC, and HEASARC, as well as PSU, Omitron, Spectrum Astro, the International Data Centers, and ASI.

Post-launch, the GNEST will continue to meet on a regular basis to review system status and revise operations plans and processes as required.

APPENDIX A – ACRONYM LIST

ADCS	Attitude Determination and Control System
AGN	Active Galactic Nucleus
arcmin	arc minute
arcsec	arc second
ASI	Italian Space Agency
ATS	Absolute Time Sequence
AZ	Arizona
BAT	Burst Alert Telescope
BATSE	Burst and Transient Source Experiment
C&DH	Command & Data Handling
CCB	Configuration Control Board
CCD	Charge Coupled Device
CCSDS	Consultative Committee for Space Data Systems
CGRO	Compton Gamma-Ray Observatory
CMD	Command
COP-1	Command Operation Procedure - 1
COTS	Commercial-Off-The-Shelf
CPU	Central Processing Unit
CTV	Compatibility Test Van
DAS	Demand Access System
DTAS	Data Trending and Analysis System
E/PO	Education and Public Outreach
ETE	End-To-End
ETR	Eastern Test Range
FDF	Flight Dynamics Facility
FITS	Flexible Imaging Transport System
FoM	Figure of Merit
FOT	Flight Operations Team
FOV	Field of View
GCN	GRB Coordinates Network
GNEST	Ground Network for Swift
GOTS	Government-Off-The-Shelf
GRB	Gamma-Ray Burst
GSFC	Goddard Space Flight Center
HEASARC	High Energy Astrophysics Science Archive Research Center
I&T	Integration & Test
IFC/CNR	Instituto di fisica CosmicaIM Instrument Module
IONet	Internet Protocol Operational Network
IP	Internet Protocol
IR	Infra-Red
ISAC	Italian Swift Archive Center
ISP	Internet Service Provider
ISWG	International Science Working Group

ITOS	Integrated Test and Operations System
keV	Thousand electron Volts
kbps	Thousand bits per second
KSC	Kennedy Space Center
L&EO	Launch & Early Orbit
L	Launch
LAN	Local Area Network
LANL	Los Alamos National Laboratory
L0	Level Zero
m	meter
MA	Multiple Access
Mbps	Million bits per second
MCP	Micro-Channel Plate
MDR	Mission Design Review
MIDEX	Medium-class Explorer
msec	millisecond
MOC	Mission Operations Center
MSSL	Mullard Space Science Laboratory
NASA	National Aeronautics and Space Administration
NCC	Network Control Center
NFI	Narrow Field Instrument
nm	nanometer
NM	New Mexico
NORAD	North American Air Defense Command
OAB	Astronomical Observatory of Brera
OGIP	Office of Guest Investigator Program
OIG	Orbital Information Group
OJT	On-the-Job-Training
PA	Pennsylvania
PAPA	Predict Ahead Planner Algorithm
PB	Playback
PDB	Project Database
PDMP	Project Data Management Plan
PDR	Preliminary Design Review
PI	Principal Investigator
PM	Project Manager
PSLA	Project Service Level Agreement
PSU	Penn State University
RF	Radio Frequency
RS	Reed-Solomon
RT	Real-Time
RTS	Relative Time Sequence
SAA	South Atlantic Anomaly
S/C	Spacecraft
SCP	Stored Command Processor
SAX/SOC	Satellite per Astronomic/Science Operations Center

SDC	Swift Data Center
sec	second
SN	Space Network
SOC	Simulations Ops Center
SOH	State of Health
SOT	Science Operations Team
SRD	System Requirements Document
SSC	Swift Science Center
SSR	Solid State Recorder
STDN	Spacecraft Tracking and Data Network
STK	Satellite Tool Kit
STOL	Spacecraft Test & Operations Language
SWSI	SN Web Services Interface
TBD	To Be Determined
TCP	Transmission Control Protocol
TCS	Thermal Control System
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TLM	Telemetry
ToO	Target of Opportunity
UCB	University of California at Berkeley
UCL	University College London
UK	United Kingdom
UKDC	United Kingdom Data Center
UL	University of Leicester
U.S.	United States
USN	Universal Space Network
UV	Ultra-Violet
UVOT	Ultra-Violet Optical Telescope
VME	Versa Module Eurocard
VP	Vice President
VPN	Virtual Private Network
WDISC	WSC TCP/IP Data Interface Service Capability
WSC	White Sands Complex
WWW	World Wide Web
XMM	X-Ray Multi-Mirror
XRT	X-Ray Telescope
ZMB	Zero Momentum Bias